This study was financially supported by the Brazilian agency CAPES (Coordination for Improvement of Higher Education Person-
nel), grant number PROSUP 0012/02-5.


3. The 10-mm post length groups had significantly higher (P <.001) mean initial fracture loads when compared with the 5-mm post length groups.

4. The mode of initial failure for all groups was core debonding from the tooth.

5. The mode of ultimate failure for groups varied. The stainless steel posts had an incidence of 25% root fractures, while no root fractures were observed with fiber-reinforced posts.


10. Currerm CJ, Bums DR, Moon P. In vitro comparison of the fracture resistance and failure mode of fiber, ceramic, and con-


17. Newman MP, Yaman P, Dennison J, Rafter MC, Paulino, PhD, a Luiz Pascoal Vansan, PhD, b Manoel Damiao de Sousa Neto, PhD, c and Silvana Maria Paulino, PhD,d University of Ribeirao Preto (UNAERP), Ribeirao Preto, Sao Paulo, Brazil; Faculty of Dentistry of Ribeirao Preto University of Sao Paulo (FORP-USP), Ribeirao Preto, Sao Paulo, Brazil.

Statement of problem. Dental fractures can occur in endodontically treated teeth restored with posts.

Purpose. The purpose of this study was to evaluate in vitro fracture resistance of roots with glass-fiber and metal posts of different lengths.

Material and methods. Sixty endodontically treated maxillary canines were embedded in acrylic resin, except for 4 mm of the cervical area, after removing the clinical crowns. The post spaces were opened with a cylindrical bur at low speed attached to a surveyor, resulting in preparations with lengths of 6 mm (group 6 mm), 8 mm (group 8 mm), or 10 mm (group 10 mm). Each group was divided into 2 subgroups according to the post material: cast post and core or glass-fiber post (n = 30). The posts were luted with dual-polymerizing resin cement (Panavia F). Cast posts and cores of Co-Cr (Resilient Plus) crowns were made and cemented with zinc phosphate. Specimens were subjected to increasing compressive load (N) until fracture. Data were analyzed with 2-way ANOVA and the Tukey-Kramer test (α = 0.05).

Results. The ANOVA analysis indicated significant differences (P < 0.05) among the groups, and the Tukey test revealed no significant difference among the metal posts of 6-mm length (26.5 ± 3.34 mm), 8-mm length (25.2 ± 3.19 mm), and 10-mm length (17.1 ± 5.24 mm). Also, in the glass-fiber post group, there was no significant difference when posts of 8-mm length (13.4 ± 1.10 mm) were compared with the 6-mm (6.9 ± 4.6 mm) and 10-mm (13.1 ± 7.3 mm) groups. The 10-mm-long post displayed superior fracture resistance, and the 6-mm-long post showed significantly lower mean values (P < 0.01).

Conclusions. Within the limitations of this study, it was concluded that the glass-fiber post represents a viable alternative to the cast metal post, increasing the resistance to fracture of endodontically treated canines.

J Prosthet Dent 2009;101:183-188

Clinical Implications. In situations involving small and/or curved roots, the glass-fiber post with a smaller length represents a viable alternative to restore endodontically treated canines requiring prosthodontic restoration, without decreasing the resistance to fracture.
Endodontically treated teeth with extensive loss of coronal tooth struc-
ture are commonly restored with a post and core system.1 Other authors
indicating this type of restoration include extensive dental caries, fracture,
trauma, iatrogenic loss of tooth structure and pulpal pathology, as well as
the common bacterial leakage. In addition, the loss of water content in
dentin after endodontic therapy can reduce tooth resilience and, conse-
quently, increase the probability of fracture.2

After endodontic treatment, the restoration of pulpal teeth is im-
portant to ensure successful treat-
ment outcomes. Restorations provide protection and reinforcement of
the tooth, and also prevent the passage of microorganisms and organic acids
into root canals.3 Failure involving the post and the crown can result in
fracture of the post and root, and dis-
placement or loss of retention of the
post. Fracture of the remaining tooth
structure is one of the most frequent causes of failure.4

Cast metal posts and cores have been used for many years; however, there are now newer post systems available. Among the materials used for
endodontic treatment of restoration posts, glass fiber has gained popularity because of its purported favorable biome-
chanical properties.5,6 They are re-
portable to be more flexible than cast metal and provide a better distri-
bution of forces, resulting in fewer root fractures.7 In addition, these pre-
fabricated posts are advantageous in situations in which adequate coronal tooth structure is not available.8 Prefab-
ed posts are classified according to the structural composition as met-
al, ceramic, or resin reinforced with fibers.8,9

Some authors have reported that endodontically treated teeth restored with fiber posts show a decreased fracture resistance compared with teeth restored with metal posts.10 Other authors, however, have in-
dicated that the fracture resistance of teeth restored with glass-fiber posts is
equal to or greater than that of teeth restored with metal posts. Studies sug-
uggest that the fracture susceptibility of teeth restored with posts may be related to factors such as the amount of remaining healthy
of the root structure, which provides resis-
tance to the fracture of the tooth, as much as the material composition,1,17
modulus of elasticity,7,18 diameter,19 and
length. Some authors20,21 have indicated that the length of the post is related to root fracture, and that the post should be two thirds of the length of the root, or, when this can-
not be achieved, the post should have a length equal to the clinical crown. According to Braga et al.,22 if neither goal can be reached, the post
must extend at least half of the root length. The authors observed that posts that extended to half of the root length behaved similarly to those that were two thirds of the root length. Furthermore, such posts preserve a greater amount of root canal filling material.23 This is important considering that the apex is an area of greater anatom-
ical complexity, with a high number of lateral and accessory canals.24,25

The purpose of this in vitro study was to evaluate the fracture resistance of roots with cast posts and cores and glass-fiber posts of different lengths by using a compressive test. The null hypothesis was that there would be no difference in the fracture suscepti-
bility of endodontically treated can-
nines restored with different types of post systems of different lengths.

MATERIAL AND METHODS

Sixty caries-free and restoration-
free human maxillary canines with roots of similar form were selected. All teeth had been restored with fiber posts, and straight roots measuring approximately 16 mm. The clinical crowns were sectioned transversely, close to the cemento-enamel junction, leaving a 2-mm-thick dentin slice. The exploration of the radicular car-
ral canal was accomplished with #25 K-files (Dentsply Maillefer, Ballaigues, Swit-
zzerland) to select the specimens that had a working length of 14 mm and an anatomically normal root canal. The preparation of the entrance of the radicular canal was accomplished with a flaring instrument (EndoFlare II, no. 12, no. 25, Micro-Mega, Besançon, France); working length was determined according to the post and the crown can result in
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preparation, the canals were irrigated with 2 ml of 1% sodium hy-
pochlorite. This was standardized for all specimens. The coronal 150-µm aluminum oxide (Gold-
ent; AE Goldent Comercial Ltda, São Paulo, Brazil). Beginning with this standard mold, 60 acetate cement (Kuraray Co Ltd), following
mold was made in the anatomical form of a core of the complete crown of masticatory canal teeth, which was casted in the acrylic integral crown (gold-
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Endodontically treated teeth with extensive loss of coronal tooth structure are commonly restored with a post and core followed by a crown. 

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To obtain groups GPF 6 mm, GPF 8 mm, and GPF 10 mm, the glass-fiber posts were cemented with Panavia F (Kuraray Co Ltd). The same post and core system used for the other groups was used for each group.

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application on the cingulum of the palatine root. An oblique compressive load was applied to the long axis of the roots. An inspec-tors at the base of the apparatus was subjected to a compressive test in a universal testing machine (±2°C), for a period of 72 hours. Excess cement was removed with a 60-second procedure. After 10 minutes, the excess cement was removed with a dental explorer. The specimens were stored in 100% relative humid-ity, at a constant temperature of 37°C (±2°C), for a period of 72 hours. The specimens were then subjected to a compressive test in a universal testing machine (Instron 4444; Instron Corp, Norwood, Mass). A device used to standardize the position of the specimens at the base of the apparatus so that the load could be applied at an angle of 135 degrees in relation to the long axis of the roots. An increasing oblique compressive load was applied on the cingulum of the palatine surface (3.0 mm from the incisor region) by using a cylindrical-shaped device with a round terminus (2.7 mm in diameter). A crosshead speed of 1 mm/min was applied until the root fractured. The set of root-post frag-ments were removed from the acrylic base and stored by using cast metal and glass-fiber posts. The fracture percentage values are distributed, data were transformed to an angle percentile-transformed data. A two-way ANOVA was performed with the transformed data (P<.05). The Tukey-Kramer test was used to verify which groups differed among themselves (P<.05).

RESULTS

The mean values of the compressive loads required to fracture the roots in each of the 6 groups are displayed in Table I. The ANOVA indicated significant differences (P<.05) among the groups (Table II), and the Tukey-Kramer test (Table III) showed no statisti-cal differences among the metal posts of different lengths: 6 mm (26.5 N ±13.4), 8 mm (25.2 N ±13.9), and 10 mm (17.1 N ±5.2). For the glass-fiber post group, the 8-mm posts (13.4 N ±11.0) were statistically similar to the 6-mm (6.9 N ±4.6) and 10-mm posts (31.7 N ±13.1). After the compression test, the post fragments were removed from the radicular canal for evaluation of the type and location of fractures. The fracture percentage values are shown in Table IV.

DISCUSSION

The current study evaluated the resistance to fracture of roots restored with different post systems and different lengths. The results of the current study support rejection of the null hypothesis that there would be no difference in the fracture of endodontically treated teeth restored with different types of post systems and different lengths. Analysis of the results indicates that the length of cast posts did not affect the resistance of the roots to fracture. The authors hypothesize that, regardless of the length, when a rigid cast post with a high modulus of elasticity is submitted to stress or an oblique compressive load, it does not absorb the energy. Rather, it transmits energy to a less rigid structure, in this case, the dentin, which has a lower modulus of elasticity, thus in-creasing the fracture potential of the root.7 Hayashi et al17 noted that the fractur-ing of teeth restored with cast posts is related to the post’s stiffness. In the current study, the fracture location was predominantly in the apical region, probably because of the oblique compressive load transferred from the post to dentin in the apical region.7 With a fracture in this location, the tooth is nonrestorable.7,9,18 With respect to the glass-fiber posts, the results indicated that the roots restored with the longer posts (10 mm) had a greater resistance to fracture. Posts with a modulus of elasticity similar to dentin, such as the glass-fiber post, when subjected to a compressive load, can better absorb the forces concentrated along the root, which may decrease the probability of fracture.8,13 This phenomenon may exPLAIN the results obtained in this study for the longer posts (10 mm), which, given their larger mass volume, possessed the capacity to absorb a greater amount of stress, rather than trans-fering stress to the dentin. However, the shorter posts (6 mm) appeared to concentrate the stresses in the smaller area of radicular dentin, with a greater susceptibility to fracture.

The fracture locations for the longer glass-fiber posts (8 and 10 mm) were predominantly in the cervical region, which may result from a greater concentration of forces in this region due to the angle of the joint between the glass-fiber post and the compos-itely core. As for the 6-mm posts, there was a greater incidence of fracture in the middle region, probably because of the smaller mass volume of these posts, which resulted in a lower absorption of forces and their more efficient transfer to the dentin.

The 6-mm and 8-mm glass-fiber posts correspond, respectively, to 40% and 53.3% of the radicular length of 15 mm measured in this study. These lengths should be between one third and one half of the radicular length only in situations that do not allow the...
the manufacturer’s instructions. The crows were air borne particle abraded with 150-µm aluminum-oxide powder (Wilson, Polidental). All crows were cemented with zinc phosphate cement (Zinc Cement; SS White) in a ratio of 2.0 g of phosphate zinc powder to 0.5 ml of liquid. The crows were then covered with cement placed on the preparations, and constant finger pressure was applied for 60 seconds. After 10 minutes, the excess cement was removed with a dental engineer. The specimens were then stored in 100% relative humidity, at a constant temperature of 37°C (±2°C), for a period of 72 hours. The specimens were then subjected to a compressive test in a universal testing machine (Instron 4444; Instron Corp, Norwood, Mass). A device was used to standardize the position of the specimens at the base of the apparatus so that the load could be applied at an angle of 135 degrees in relation to the long axis of the roots. An increasing oblique compressive load was applied on the preparations, and constant finger pressure was applied for 0.5 ml of liquid. Phosphate zinc powder was used for 150-µm aluminum-oxide region by using a cylindrical-shaped device with a round terminus (2.7 mm in diameter). A crosshead speed of 1 mm/min was applied until the root fractured. The set of root-post fragments were removed from the acrylic resin, after the fracture, and observed under a stereoscopic magnifying glass (Leica Microsystems GmbH, Wetzlar, Germany), at 5× magnification, for fracture analysis. With respect to the location, the fracture was classified according to the root third in which it occurred: cervical, middle, or apical. Regarding the type, the fracture plane was considered in relation to the long axis of the root and was classified as longitudinal, oblique, or transverse. The values of the forces required for the roots to fracture, obtained in N, were submitted to preliminary statistical analysis. As for the 6-mm posts, the 8-mm posts (13.4 N ±1.0) were statistically similar to the 6-mm (6.9 N ±4.6) and 10-mm posts (31.7 N ±1.3). After the compression test, the post fragments were removed from the root canal for evaluation of the type and location of fractures. The fracture percentage values are shown in Table IV.

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DISCUSSION

The current study evaluated the resistance to fracture of roots submitted to endodontic treatment and restored by using cast metal and glass-fiber posts with different lengths. The results of the current study support rejection of the null hypothesis that there would be no difference in the fracture of endodontically treated teeth restored with different types of post systems and different lengths. Analysis of the results indicates that the length of cast posts did not affect the resistance of the roots to fracture. The authors hypothesize that, regardless of the length, when a rigid cast post with a high modulus of elasticity is submitted to stress or an oblique compressive load, it does not absorb the energy. Rather, it transmits energy to a less rigid structure, in this case, the dentin, which has a lower modulus of elasticity, thus increasing the fracture potential of the root.

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The fracture locations for the longer glass-fiber posts (8 and 10 mm) were predominantly in the cervical region, which may result from a greater concentration of forces in this region due to the angle of the joint between the glass-fiber post and the composite resin core. As for the 6-mm posts, there was a greater incidence of fracture in the middle region, probably because of the smaller mass volume of these posts, which resulted in a lower absorption of forces and their more efficient transfer to the dentin. The 6-mm and 8-mm glass-fiber posts correspond, respectively, to 40% and 53.3% of the radiographic length of 15 mm measured in this study. These lengths should be between one third and one half of the radiographic length only in situations that do not allow the

<table>
<thead>
<tr>
<th>Table I. Mean values (SD) of strength (N) of compressive force required for root fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Post Type</strong></td>
</tr>
<tr>
<td><strong>Cast post and core</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Cast post and core</strong></td>
</tr>
</tbody>
</table>

**Table II. Two-way ANOVA with angle percentile-transformed data**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>Mean Squares</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between lengths</td>
<td>0.0006</td>
<td>2</td>
<td>0.0003</td>
<td>2.54</td>
</tr>
<tr>
<td>Between types</td>
<td>0.0005</td>
<td>1</td>
<td>0.0005</td>
<td>3.87</td>
</tr>
<tr>
<td>Between groups</td>
<td>0.0032</td>
<td>2</td>
<td>0.0016</td>
<td>13.31</td>
</tr>
<tr>
<td>Residual</td>
<td>0.0065</td>
<td>54</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.0107</td>
<td>59</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table III. Tukey-Kramer test, between groups**

<table>
<thead>
<tr>
<th>Post Type</th>
<th>Means</th>
<th>Critical value (±0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast post and core, 6 mm</td>
<td>26.5±4.6</td>
<td>13.22</td>
</tr>
<tr>
<td>Cast post and core, 8 mm</td>
<td>25.2±4.6</td>
<td></td>
</tr>
<tr>
<td>Cast post and core, 10 mm</td>
<td>17.1±4.6</td>
<td></td>
</tr>
<tr>
<td>Glass-fiber post, 6 mm</td>
<td>6.9±1.5</td>
<td></td>
</tr>
<tr>
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<td>13.2±1.5</td>
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<td>31.7±1.5</td>
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</table>

Groups with same superscript letter were not significantly different according to Tukey-Kramer test (P>0.05).

**Table IV. Percentage of fractures in relation to location of root fracture according to post type and length**

<table>
<thead>
<tr>
<th>Place of Fracture</th>
<th>Cast Metal</th>
<th>Glass Fiber</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>6 mm</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>8 mm</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>10</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Apical</td>
<td>90</td>
<td>70</td>
<td>0</td>
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<table>
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<tr>
<th>Post Type</th>
<th>Cervical</th>
<th>Middle</th>
<th>Apical</th>
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<tbody>
<tr>
<td>Cast Metal</td>
<td>6 mm</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>8 mm</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>10 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass Fiber</td>
<td>6 mm</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 mm</td>
<td>40</td>
<td></td>
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<tr>
<td></td>
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Groups with same superscript letter were not significantly different according to Tukey-Kramer test (P>0.05).
optimal length, two thirds of the root, to be obtained. \(1,2\) When the length of 10 mm was used for the glass-fiber posts (66.6%, or two thirds, of the root length), the force required for the fracture of these posts was significantly greater than that required for the 6-mm-long posts. The 8-mm post showed an intermediate value which was statistically similar to the values for the 6-mm and 10-mm posts. As in the present study, Braga et al.\(^3\), working with glass-fiber and cast posts of different lengths, obtained satisfactory results for the 8-mm glass-fiber posts with respect to retention. Thus, considering that the 8-mm glass-fiber posts have demonstrated values similar to the 6- and 10-mm posts, with respect to both fracture strength and retention, their use can be recommended for situations in which the length of two thirds cannot be reached, for example, in situations involving curved roots. Based on these results, the recommendation of Shillingburg et al.\(^4\) that the intraradicular post be two thirds of the root length should be modified to suit the new prefabricated posts and adhesive material systems.

This current study has some limitations, such as the type of testing used; that is, a single cycle to failure, which does not represent the intraoral condition. Intraradicularly, teeth are subjected to cyclic loading through mastication and are immersed in a wet environment, an environment that is subject to chemical and thermal changes. The study also evaluated maxillary canines, and, therefore, the results can be applied only to that group of teeth. However, cement pressure was not standardized, as only finger pressure was used. It is also important that clinicians consider the various types of materials available for post systems, as well as their mechanical properties.Further research is necessary to clarify the effects of different lengths of new posts on the resistance to fracture. Finally, further investigations using a similar study design, but with a simulated periodontal ligament, should be used to compare the different esthetic post systems.

**CONCLUSIONS**

Within the limitations of this in vitro study, the following conclusions were drawn:

1. In relation to the length, cast posts did not differ significantly in terms of the compressive load required to fracture the root (\(P<.17\)).

2. The 10-mm-long glass-fiber group demonstrated significantly higher values of fracture resistance, and the 6-mm-long glass-fiber group showed the lowest values for the force resulting in root fracture; these groups were significantly different from each other (\(P<.001\)).

**REFERENCES**


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**CLINICAL IMPLICATIONS**

As long as restorations are seated in a timely manner, all of the products evaluated in this study demonstrate acceptable film thicknesses.

**Indirect restorations have been demonstrated to be effective, with clinical studies reporting a survival rate for single crowns of greater than 90% for 8-10 years, using current techniques.** \(^{1,2}\) Luting agents, because they join indirect restorations to their preparations, are critical to their effectiveness. In addition to possessing the low solubility and high ultimate strength necessary for long-term retention of restorations, these materials must also maintain a minimal film thickness over a long enough interval that restorations can be seated completely.

Currently, 3 classes of luting agents, resin-modified glass ionomer, composite resin, and self-etching resin, are considered to be viable clinical options. In the past, composite resin cements have demonstrated a greater film thickness than other cements, which is reflected in current ISO standards that require a film thickness of 25 µm at the time of seating. In recent years, self-adhesive resin luting cements have been introduced, and composite resin and resin-modified glass ionomer cements reformulated, but little information on the film thicknesses of these materials has been reported. The Council on Scientific \(\alpha\)